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Direct seeding is a promising means of establishing shortleaf pine (*Pinus echinata* Mill.) in the Missouri Ozarks. To insure prompt germination when direct seeding is done in the spring, stratified seed usually is used. In areas where birds and rodents are plentiful, the seed must be coated with repellents to prevent losses. After treatment, it may be necessary to store this stratified and repellent-treated seed for short periods. The study described here was made to determine how stratification time, sticker and repellent treatment, and storage time and temperature affect the viability of shortleaf pine seed from a Missouri source.

[1] The author acknowledges the assistance given during this study by Dr. G. S. Cox of the University of Missouri School of Forestry and by K. A. Brinkman of the Columbia field office of the Central States Station.

Procedures

The study was made in greenhouse facilities of the University of Missouri, using 1957 Missouri seed that had been stored in sealed containers at 32° to 36° F. Moisture content of this seed before stratification was about 22 percent.

Treatments studied were stratification for 20, 40, and 60 days at 38° to 40° F. followed by storage for 2, 15, and 30 days at 38° and 60° F. Some seed lots received no coating, others the sticker only, and the rest were treated with both sticker and a mixture of two repellents. All treatment combinations were replicated four times. There were 220 sample lots of 100 seeds each.

The polyethylene-plastic-bag method of seed stratification was used in this study.[2] Seed soaked in water at 60° to 70° F. for 24 hours was drained, sealed in plastic bags, and placed in a refrigerator (fig. 1).

Repellents and sticker were applied after stratification but before storage. The sticker used was Dow Latex 512R; repellents were Endrin 25W, a rodent repellent that also possesses insecticidal properties, and sublimed anthraquinone, a bird repellent. Two pounds of Endrin 25W (25 percent concentration) and 15 pounds of anthraquinone were applied per 100 pounds of seed.

Sand in which seed was sown had been sterilized with methyl bromide gas for 24 hours and then aerated for 3 days (fig. 2). Seed was sown on May 23, 1961. Stratification of the various seed lots began at different times so that all lots could be planted on the same day, thus eliminating any variation in germination due to different greenhouse temperatures or day lengths. Fifty-four treated samples were planted in each of four blocks. This provided all possible combinations of stratification time, seed coating, and storage time and temperature. One additional 100-seed sample of unstratified seed was planted in each of the four blocks for comparison with the stratified seed.

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[2]Hosner, John F., Richard E. Dickson, and Leslie Kahler. Storing loblolly pine seed in polyethylene bags as a substitute for stratification. Jour. Forestry 57: 495-496, illus. 1959.

FIGURE 1.—Stratification of shortleaf pine seed in polyethylene bags.

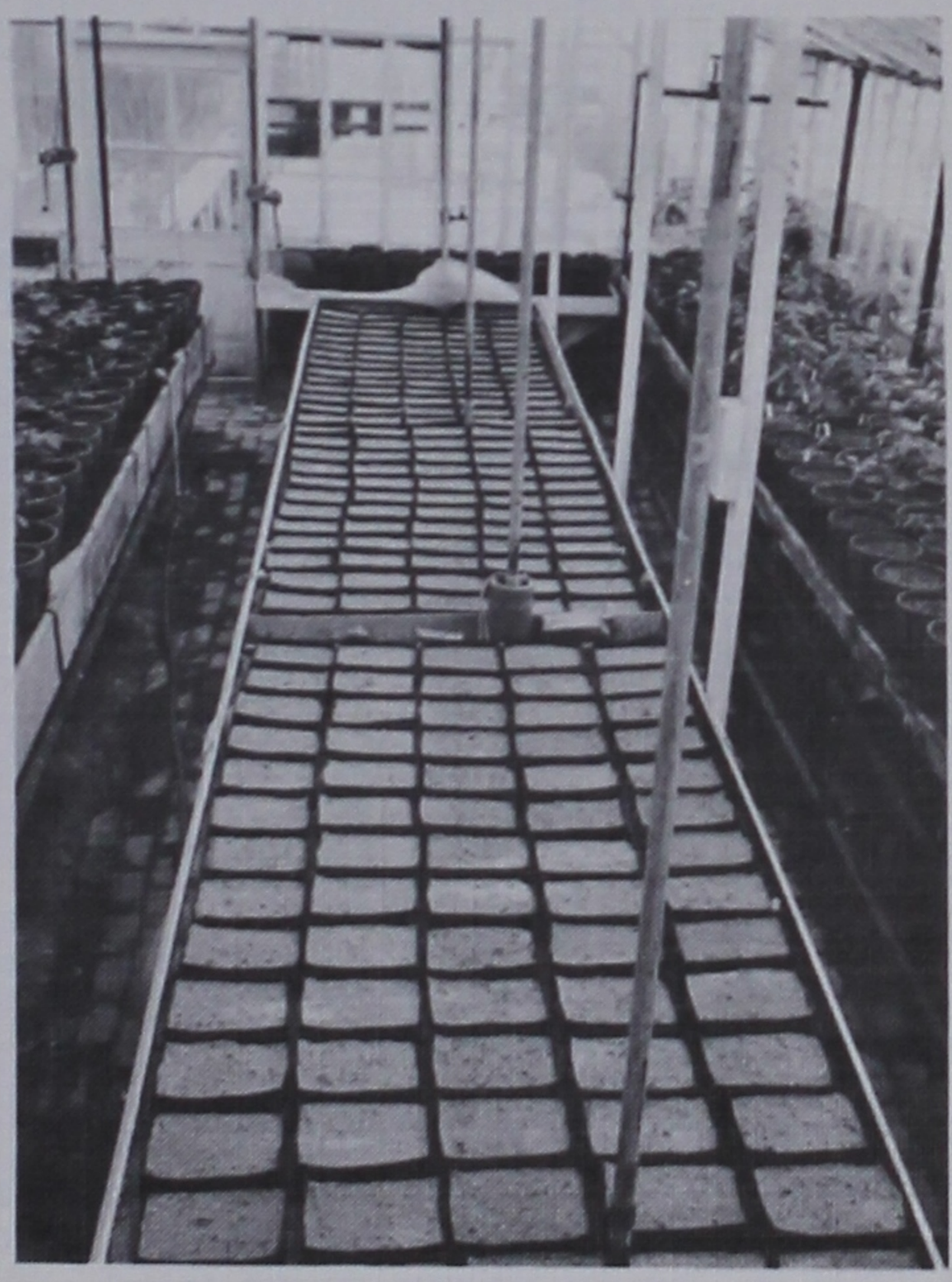

FIGURE 2.—Arrangement of the fiber-resin sand flats in the greenhouse.

Standard procedures for germination tests were followed in this study.[3,4] All seed was covered to a depth of ⅛ inch. Cumulative tallies of the seedlings whose cotyledons or adhering seed coat protruded from the sand were made every 2 days. These counts were continued for all lots for at least 30 days. Germination of unstratified seed was recorded at 5-day intervals for an additional 40 days. Each seedling was removed from the flats as tallied. Counts were made often enough so that seedlings were removed before seed coats fell from the cotyledons.

At the end of the germination period, all ungerminated seed was cut to find the number of empties. Percent germination was computed for the number of filled seeds, rather than for the 100-seed sample.

The results of this study were evaluated by means of a "germination value" (G.V.).[5] This is a single term that combines both speed and completeness of germination, promptness having more weight than completeness. High germination value indicates faster germination, more complete germination, or both. G.V. is computed as follows:

$$\text{G.V.} = \frac{\text{Germinative energy}}{\text{Germinative energy period}} \times \frac{\text{Percentage of filled seed that germinates}}{\text{Number of days over which germination is counted}}$$

Germinative energy is the percentage of filled seed that has germinated up to the day of peak seedling emergence.

Germinative energy period is the number of days required to reach this peak rate of emergence.

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[3] U.S. Forest Service. Woody-plant seed manual. U.S. Dept. Agr. Misc. Pub. 654, 416 pp., illus. 1948.

[4] Wakeley, Philip C. Planting the southern pines. U.S. Dept. Agr., Forest Serv., Agr. Monog. 18, 233 pp., illus. 1954.

[5] McLemore, B. F., and Felix J. Czabator. Length of stratification and germination of loblolly pine seed. Jour. Forestry 59: 267-269, illus. 1961.

Results

Except for uncoated seed that was stratified the longest then stored at 60° F. the longest (60 days stratification, 30 days storage), the percentage of filled stratified seed germinating was very high — from 73 to 95 percent within 30 days (table 1). In addition, stratified seed germinated much faster than did unstratified seed (fig. 5, p. 10). Although total germination of unstratified seed (88 percent) was comparable to that of stratified seed, 65 days were required, whereas some stratified seed showed 70 to 80 percent germination within 10 days. This difference is important. The sooner seed germinates after sowing, the less the opportunity for damage.

Length of Stratification

Differences in germination values between seeds stratified for 20, 40, or 60 days were not significant. Because both speed and completeness are included, germination values are similar for seed stratified 60 days and seed stratified 20 days. Stratification for 60 days results in faster but less complete germination; stratification for 20 days results in slower but more complete germination (fig. 3).

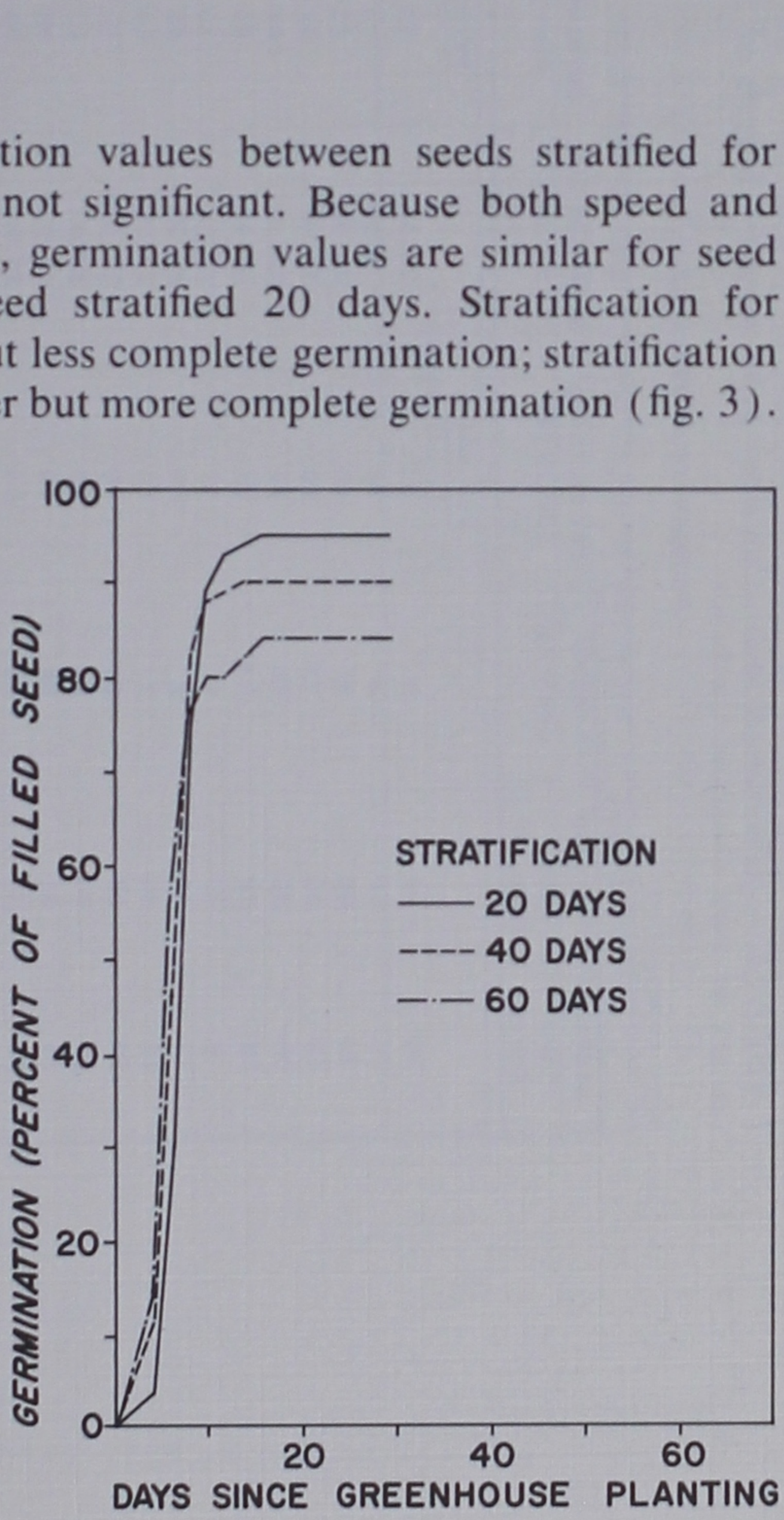

FIGURE 3.—Lengthening the stratification period increased the speed of germination but decreased the amount (seed stratified for 20, 40, and 60 days compared; all three lots were uncoated and stored at 60° F. for 15 days).

TABLE 1.—Germination of shortleaf pine seed by length of stratification period

60-DAY STRATIFICATION[1]

Treatment			Germination	Germination	Germinative	Germinative
Storage time (days)	Storage temp. (deg. F.)	Seed coating[2]	(30 days)	value	energy[3]	energy period[4]
			Percent		Percent	Days
30	38	N	84	25.68	72	8
30	60	N	48	8.56	42	8
30	38	S	85	25.10	71	8
30	60	S	86	32.06	67	6
30	38	SR	81	23.47	69	8
30	60	SR	74	23.49	62	6
15	38	N	88	28.39	78	8
15	60	N	84	27.50	68	7
15	38	S	90	27.09	81	9
15	60	S	87	32.61	67	6
15	38	SR	79	20.67	66	8
15	60	SR	78	24.62	75	8
2	38	N	86	24.39	73	8
2	60	N	90	29.87	80	8
2	38	S	88	25.00	77	9
2	60	S	86	26.45	74	8
2	38	SR	81	20.74	69	9
2	60	SR	78	18.86	58	8

40-DAY STRATIFICATION[1]

30	38	N	88	28.45	78	8
30	60	N	79	23.46	70	8
30	38	S	91	30.92	85	8
30	60	S	86	29.07	81	8
30	38	SR	83	21.87	64	8

2	38	S	86	22.84	76	10
2	60	S	88	24.57	79	10
2	38	SR	82	19.23	70	10
2	60	SR	84	22.46	76	10

20-DAY STRATIFICATION[1]

30	38	N	88	23.63	77	10
30	60	N	88	25.80	75	8
30	38	S	88	24.01	77	10
30	60	S	92	33.11	86	8
30	38	SR	85	23.18	77	10
30	60	SR	84	25.97	74	8
15	38	N	92	26.97	88	10
15	60	N	95	30.57	81	8
15	38	S	90	24.25	81	10
15	60	S	88	29.21	80	8
15	38	SR	88	22.17	77	10
15	60	SR	82	25.34	74	8
2	38	N	77	16.22	63	10
2	60	N	81	19.57	72	10
2	38	S	84	20.67	74	10
2	60	S	87	22.70	78	10
2	38	SR	82	17.95	65	10
2	60	SR	82	19.36	71	10

UNSTRATIFIED

	[5]/70	4.17	57	17

[1]/ Temperature maintained during stratification was 38° to 40° F.

[2]/ Seed coating is indicated by N for none, S for sticker only, and SR for sticker plus repellents.

[3]/ Germinative energy is the percentage of filled seed that has germinated up to the day of peak seedling emergence.

[4]/ Germinative energy period is the number of days required to reach peak emergence.

[5]/ Total germination of unstratified seed at 70 days was 88 percent of filled seed.

Seed Coatings

Of the three seed coatings, sticker by itself gave the largest "germination values," and sticker plus repellents resulted in the smallest values. This relation can also be seen in the cumulative germination curves where the only difference in the treatment received by these seed lots is the seed coating (fig. 4). Each treatment differed significantly from the other two.

Better germination results from the sticker treatment because it prevents loss of moisture and excessive drying of the seed, especially during an extended storage period. This effect is most noticeable when comparing uncoated and sticker-treated seed stratified the longest, then stored at the highest temperature the longest (stratified for 60 days and stored at 60° F. for 30 days). The uncoated seed has a germination value of 8.56, the lowest except for the unstratified seed, while the sticker-treated seed has a germination value of 32.06, one of the highest (table 1).

The slightly slower and less complete germination of the repellent-treated seed may have been caused by accumulation of repellent

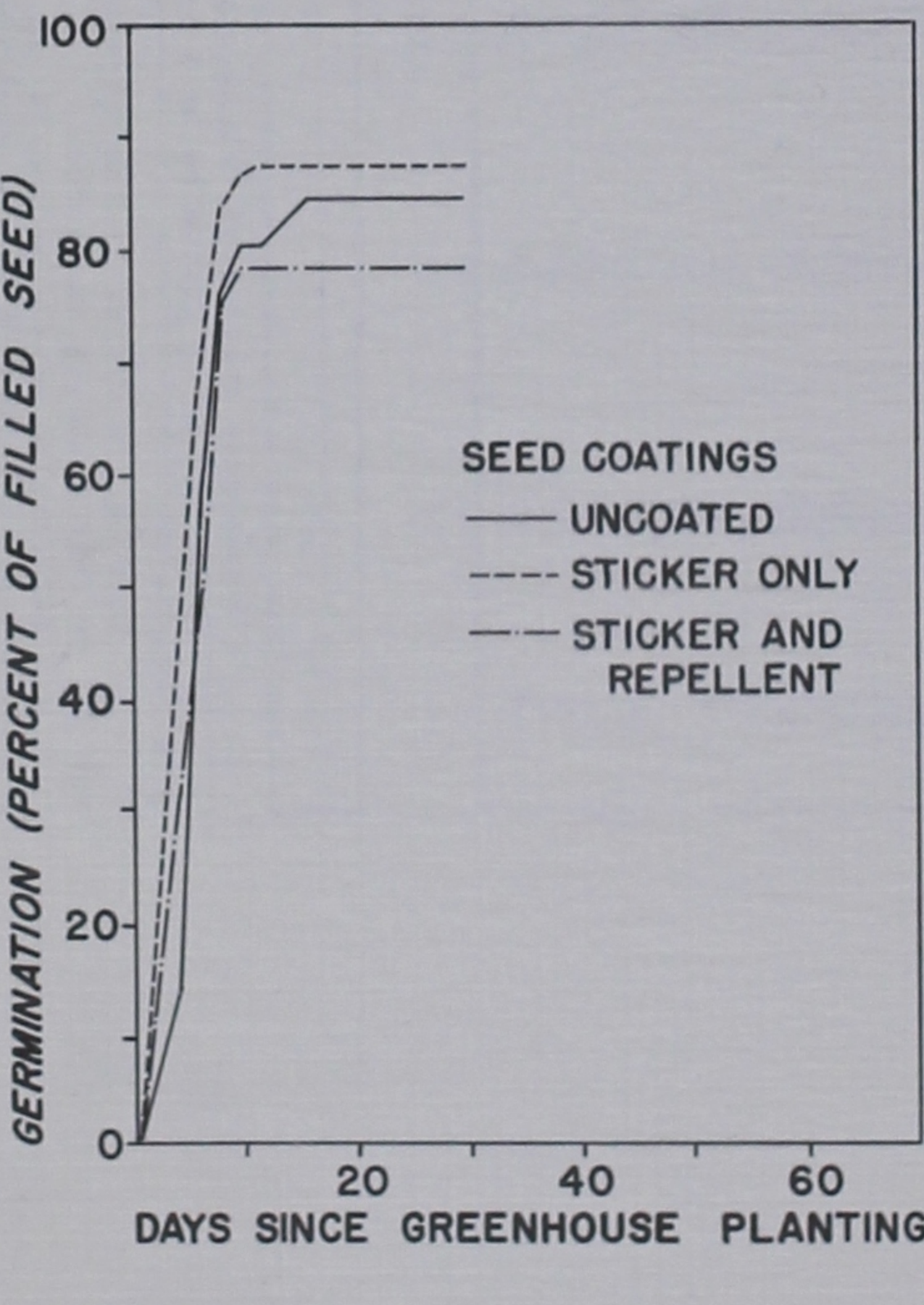

FIGURE 4. — Seed coating reduced germination somewhat (uncoated seed, seed treated with sticker alone, and seed treated with both sticker and repellents compared, all three having been stratified for 60 days and stored at 60° F. for 15 days).

chemicals in the sand flats with a resulting toxic effect on the seeds. When such repellent-treated seed is sown in the field, however, the amount of seed per unit of area will be far less than in the flats and the chemicals will be more readily washed away. Thus repellents should not decrease germination as much in practice.

Although germination values for seed treated with repellents were significantly lower than for seed to which merely sticker or no coating at all was applied, germination was not reduced enough to offset the protection given by these repellents. For example, repellent-treated seed stratified 20 days and stored at 38° F. for 2 days has a germination value of 17.95, lower than any other seed treated with repellents (table 1). Still, this represents 82 percent germination, 65 percent of it within 10 days, adequate for either direct seeding or nursery use.

Length of Storage

Length of the storage period made a significant difference in germination values. For seed stored either 15 or 30 days after stratification, germination values were nearly identical, but seed stored for 2 days had significantly lower values. Lengthening the period of either stratification or storage hastened germination, but decreased the amount.

Thirteen of the eighteen seed lots stored for 30 days contained a mold (*Penicillium* spp.). Surprisingly, this mold did not reduce the viability of even those seed lots that were completely covered with mycelia. Although no reduction in germination values was attributed to the mold in this study, moldy seed is not easy to handle in direct seeding and there is always the possibility that the action of a destructive mold may result in the loss of a valuable batch of seed.

Storage Temperature

Seed stored at 60° F. germinated faster than seed stored at 38° F., but not as completely (fig. 5). Thus germination values for the seed stored at 60° F. were significantly larger than those for seed stored at the lower temperature.

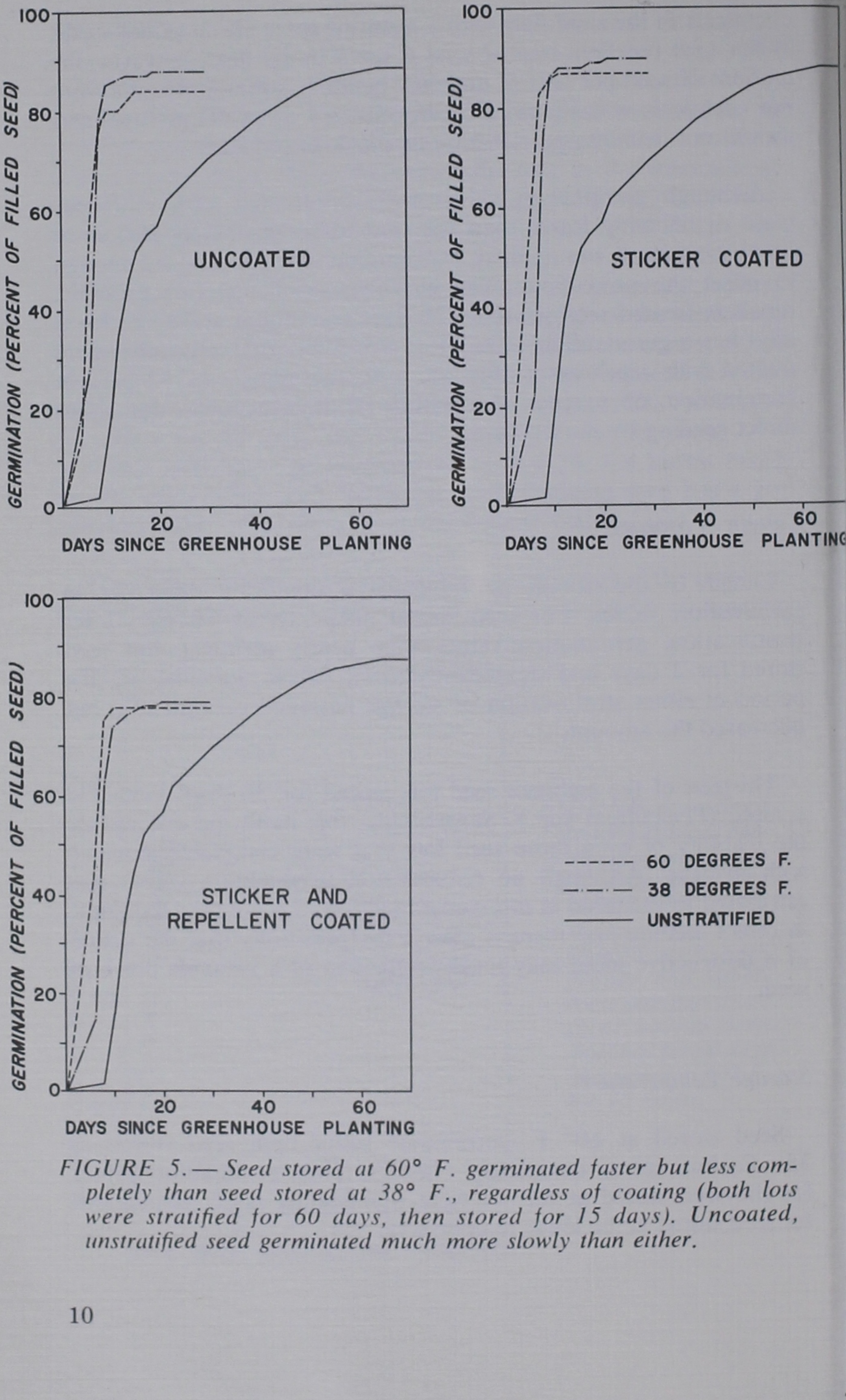

FIGURE 5.— Seed stored at 60° F. germinated faster but less completely than seed stored at 38° F., regardless of coating (both lots were stratified for 60 days, then stored for 15 days). Uncoated, unstratified seed germinated much more slowly than either.

Raising the storage temperature had the same effect as lengthening the stratification and storage periods: germination was faster though the amount decreased. This may be because more stored foods in the seed were converted to a soluble form, thus favoring prompt germination.

Uncoated seed stored at 60° F. for 15 or 30 days germinated prematurely. The amount was directly proportional to the combined stratification and storage time. For example, approximately 27 percent of uncoated seed stratified 60 days, then stored at 60° F. for 30 days, was lost through premature germination. In contrast, only 8 percent of uncoated seed stratified 20 days, then stored at 60° F. for 15 days, was lost this way.

Conclusions and Recommendations

The most striking result of this study is the fact that storage of stratified seed for up to 30 days at relatively high temperatures did not reduce viability. In fact, such seed stored for 15 or 30 days germinated faster than seed stored for only 2 days. This does not mean that all stratified seed should first be stored before using. It does, however, increase flexibility in scheduling of direct-seeding operations. Stratified seed can be stored satisfactorily at 38° to 40° F. for periods of up to 15 days if it is necessary to delay sowing until weather conditions are favorable.

Sometimes no refrigeration is available. Storage of repellent-treated seed for a few days in an unheated building should not reduce germination as long as air temperatures are below 60° F. In any case, all stored stratified seed should be checked frequently for premature germination, heating, and mold.

These results suggest that stratifying seed for as much as 70 days might give maximum germination values because of the faster germination. This would be satisfactory for small seed lots, as in this study. For larger seed lots, however, a shorter stratification period of from 30 to 50 days is recommended to reduce the chance of losing valuable seed through heating or mold formation. Seed being stratified for longer than 30 days should be examined frequently.

Only seed that has been treated with bird and rodent repellents should be sown, particularly in areas where these eaters of seed may be concentrated. The repellents used to treat seed in this study, Endrin and anthraquinone, significantly lowered germination values, but they did not reduce viability nearly enough to make their use impractical. It is better to accept somewhat poorer germination than to risk complete failure.

This study demonstrated that stratifying shortleaf pine seed before sowing in the spring is useful because it hastens germination. Coating, storage time, and storage temperatures affected germination values somewhat, but these differences had little practical importance. With the exception of unstratified seed and of uncoated seed stratified for 60 days and stored at 60° F. for 30 days, all treatments used in this study resulted in germination that was adequately rapid and complete.

The Central States Forest Experiment Station is headquartered at Columbus, Ohio and maintains major field offices at:

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